# RESTORATION OF COASTAL WETLANDS IN SOUTHEASTERN FLORIDA

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**ABSTRACT**

Rapid urbanization and associated coastal development in southeastern Florida over the last 100 years have virtually eliminated the low coastal wetlands along approximately 21 miles (34 kilometers) of mainland shoreline and approximately 12 miles (19 kilometers) of barrier island shoreline bordering Biscayne Bay. These wetland communities, which are essential to the general health of the estuarine ecosystem, were replaced by eroding, unconsolidated shorelines, and bulkheads. Historical wetlands are being restored on publicly owned lands through cooperative efforts of federal, state, and local agencies. The restoration process has involved removing fill and bulkheads, establishing species-specific elevation grades, creating flushing channels, removing exotic trees, and planting wetlands vegetation. In addition, unconsolidated shorelines are being stabilized and enhanced with mangroves and associated lime-rock protection barriers. This paper reviews ten coastal wetlands restoration projects in Miami-Dade County, Florida. In the first decade of implementing of the Biscayne Bay Restoration and Enhancement Program, Miami-Dade Department of Environmental Resources Management (DERM) has restored and enhanced approximately 300 (121.5 hectares) acres of wetlands, using cost-effective techniques learned from the experience of implementing these successful projects.

**Key Words: Wetlands, restoration, mangroves, marsh grasses, Biscayne Bay, creation, enhancement.**

## I. <u>Introduction</u>

During the early 1900s, the importance of wetlands to man and nature was not very well appreciated nor was it even known. Society viewed wetlands as valueless, unproductive tracts of land and as breeding areas for mosquitoes and disease. In southeastern Florida development of reclaimed swamp-lands, uplands and newly created lands produced by dredging and filling practices essentially began with the completion of the Florida East Coast Railroad in 1896 (Harlem, 1979). By the mid 1900s, an extensive network of drainage and flood control canals had been completed, which significantly altered how freshwater was delivered to southeastern Florida coastal areas. These regional modifications of freshwater inflow, plus past dredging and filling practices associated with rapid urbanization, caused serious environmental degradation to southeastern Florida coastal wetlands and estuaries (Tabb, 1963, Idyll, 1965b; Idyll and others, 1968; Odum, 1971). The Biscayne Bay estuary, located on the southeast coast of Florida, suffered increased salinities, and natural communities were lost or severely altered relative to the historical condition. In addition, the southeast coast of Florida is affected by occasional hurricanes and tropical storms, which profoundly affect Biscayne Bay.

Biscayne Bay is on the eastern coast of Miami-Dade County (Greater Miami) and is enclosed by a series of barrier islands and vegetated submerged banks that separate it from the Atlantic Ocean (Figure 1). The bay extends approximately 35 miles (56.4 ha) from north to south, and varies in width from less than one mile (1.6 ha) to approximately eight miles (12.9 ha), covering an area of 220 square miles (570 sq. hectares). The northern third of the bay (North Bay) has been most severely affected by development, and is subdivided by six filled causeways and a seaport facility. In North Bay, low coastal wetlands have been virtually eliminated and over forty percent of the bay bottom communities were altered by spoil emplacement and dredging (Harlem, 1979).

The ecological importance of coastal wetland as habitat and a vital link in the marine food web have been well documented (Idyll and others, 1968; Odum and Heald, 1972; Heald and others, 1974; Odum and others, 1982; Jansson and others, 1988). Florida mangrove communities are important habitats for a wide variety of fish, reptiles, amphibians, birds, and mammals, including at least seven endangered species, five endangered sub-species, and three threatened species (Odum and others, 1982). In addition, south Florida mangrove wetlands stabilize shorelines, especially during hurricanes (Scoffin, 1970; Carlton, 1974; Lodge, 1974). Inter-tidal salt marshes are limited in south Florida because of the competition for suitable substrates with mangroves (McNulty and others, 1972). Marshes are typically found in the transition zone between the marine and fresh water environments.

Loss of southeastern Florida coastal wetland habitat over the last 100 years, along with a growing body of scientific evidence documenting the importance of coastal wetlands, has resulted in government regulatory protection and habitat re-establishment, particularly through restoration and enhancement.

The goal of the Miami-Dade County Department of Environmental Resources Management (DERM) Coastal Wetlands Restoration Program, is to restore, to the extent possible, native communities to levels of historical ecological functions. In Miami-Dade County, three types of emergent wetland communities are being restored: mangrove forest, saltmarsh and fresh/brackish water wetlands. In this paper, I review the design and implementation of ten coastal wetlands restoration projects in Miami-Dade County, Florida (see Figure 2).

## II. Development of the Restoration Plan

In these ten projects, restoration plans were developed through review of historical documents (aerial photographs and literature) and field investigations of site characteristics. Field investigations include topographic, biological, geo-technical, hydrological, and archaeological review of the prospective site. This information has been found to be necessary to protect existing natural resources and to identify the limits and details of restoration activities. This review provides information that is utilized in developing a detailed final design, accurate cost estimate, environmental permitting, funding requests, construction plans and specifications for the contractor selection process.

All potential wetland restoration project sites are prioritized by public ownership (to ensure long-term protection); habitat benefit considerations to the surrounding natural areas; site accessibility for heavy equipment; and cost effectiveness. Requests by other departments or agencies to conduct specific restoration or mitigation efforts were considered when prioritizing project sites.

Biological components – A comprehensive biological assessment was conducted to: document existing on-site and surrounding biological communities; identify environmental concerns; define biological goals and objectives; and make specific recommendations concerning construction activities associated with the projects. Surrounding ecological conditions assists in developing target species, planting elevations and hydrological connections. The biological assessment is also a key element of local, state and federal required environmental resources permit applications.

Typically, disturbed or altered wetlands often contain exotic uplands species such as Australian pine (*Casuarina equisetifolia*), Brazilian pepper (*Schinus terebinthifolius*), Burma reed (*Neyraudia reynaudiana*), Seaside mahoe (*Thespesia populnea*) and Beach naupaka (*Scaevola taccada*). Selective clearing of these exotics is conducted to save desirable upland native species observed on-site. Native upland species often are incorporated into the overall restoration plan of tree islands, upland amenities, etc. Desirable upland species often are transplanted to areas proximal to the restoration work or buffer.

An extensive body of literature exists pertaining to mangrove planting techniques for restoration in Florida (Darovec and others, 1975; Pulver, 1976; Teas, 1977, 1981; Goforth and Thomas, 1980; Lewis, 1990a; Kusler and Kentula, 1990; Crewz and Lewis, 1991). Wetlands creation has been accomplished through deposition of material on shallow sub-tidal bottoms, and through the excavation of uplands (La Salle and others, 1991; Moy and Levin, 1991; Minello and others, 1994).

Zonation of saline wetland vegetation has been studies in great detail. (McMillan, 1971; Kuenzler, 1974; Davorec and others, 1975; Provost, 1976; Pulver, 1976; Teas, 1977; Goforth and Thomas, 1980; Teas, 1981; Odum and others, 1982; Woodhouse and Knutson, 1982; Stephen, 1984; Beever, 1986; Lewis, 1990a). In general, the species and distribution of mangroves and marsh plants within the inter-tidal zone is a result of the elevation requirements. Three mangrove species and one marsh grass are being restored in Miami-Dade County within the following elevation ranges (National Geodetic Vertical Datum [NGVD]) with the average Mean High Water (MHW) at elevation +1.5':

| | |
|---|---|
| *Rhizophora mangle* (red mangrove) | 1.0' – 1.2' |
| *Avicennia germinans* (black mangrove) | 1.25' – 1.5' |
| *Laguncularia racemosa* (white mangrove) | 1.5' – 2.0' |
| *Spartina spartinae* (gulf cordgrass) | 2.1' – 2.5' |

*Rhizophora mangle* seedlings and saplings are grown and planted through contract or planted by volunteers, if funding is limited. Plants can be obtained from native-plant nurseries. When large quantities or unavailable species are desired, it may be necessary to engage in contract growing. One-year-old red mangroves are planted on three-foot centers. *Avicennia germinans* and *Laguncularia racemosa* will recruit and are not generally planted, because they successfully colonize at a much faster rate and greater density than *Rhizophora mangle* (Milano, unpublished). *Spartina spartinae* is grown and planted or transplanted from healthy donor sites through contract. High marsh species such as saltmeadow cordgrass (*Spartina patens*), sand cordgrass (*Spartina bakeri*), saltgrass (*Distichlis spicata*), needle rush (Juncus roemerianus), golden leather fern (*Acrostichum aureum*) and sea ox-eye daisy (*Borrichia frutescens*) are planted above 2.5' NGVD.

Zonation of tidal freshwater marshes is less distinct than in many other aquatic or wetland environments. In addition, the frequency and duration of flooding is the primary factor governing species distribution (Odum and others, 1984). Commonly planted freshwater species in Miami-Dade County are *Cladium jamaicense* (sawgrass), *Eleocharis cellulosa* (spike rush), and *Scirpus validus* (Soft-stem bulrush). Freshwater wetlands are designed with very gradual 10:1 slopes (when feasible) with maximum wetland depths ranging from 0.0'-(+)0.5' N.G.V.D. Groundwater levels have been recorded at sites 1 and 2 at (+)1.0 N.G.V.D.

Desirable wetlands habitat heterogeneity is developed by providing low energy and shallow water areas. These areas are used by larvae and juveniles of desirable fish and wading birds. (Crewz and Peters, pers. Comm.). These site-specific design elements are incorporated into the preliminary design.

Hydrographic evaluations Pre-design surveys are conducted for wave energy, tidal regime, current velocity, and bathymetry. All hydrographic data is converted to NGVD to provide a standard reference for all restoration documents (i.e. permit drawings, construction drawings, etc.) The importance of the hydrological connection at mangrove restoration efforts; has been reported (Cintron, 1990; Crewz and Lewis, 1991). For large-scale projects, final project design components such as flushing canals (number, size, and depth), culverts(s) (number, size, and elevation), and open-water areas within the wetland are evaluated using a numerical model simulation. Additionally, ground-water monitoring wells may be used to evaluate seasonal ground water fluctuations for wetlands partially or completely isolated from tidal waters.

Geo-technical evaluations – Using a network of fixed stations along transects, subsurface soil characteristics are determined through a variety of techniques, including excavation of test pits, soil borings, ground penetrating radar, and electronic conductivity. Test pits, excavated by backhoe, provide a cost-effective method by which systematic sampling can be performed, to analyze trends in vertical and horizontal distribution of soil strata. A minimum of two test pits or soil borings per acre is necessary to evaluate site soil conditions.

The re-establishment of altered historical wetlands typically involves the excavation, removal, and disposal of large quantities of fill. Cost-effectiveness of public restoration is maximized through the resourceful spoil disposal strategies (truck, barge distances) or fill marketing opportunities, to reduce restoration costs. Soil classification reports are prepared for large-scale restoration projects. These reports, include detailed soil characteristics (i.e. type, grain size, distribution, color, etc.) and can provide information applicable to developing marketing, and spoil disposal strategies. For example, soil classification report prepared for Site 2 assisted in the removal, at no cost, of 250,000 (327,500m3) cubic yards of soils prior to the restoration contract.

Ground penetrating radar (GPR) and electronic surveying (ES), which provide data on subsurface conditions, have been employed in large-scale wetland restoration projects to identify the historical locations of filled wetlands. GPR produces a continuous cross-sectional profile of shallow subsurface conditions. ES is also used to measure subsurface conductivity. Electrical conductivity is a function of the type of soil and rock, their porosity and permeability, and the composition of subsurface groundwater (Technos Inc., 1994). GPR and ES were used at Site 2 (see Appendix) to locate five historical isolated wetlands that were filled to +6.5 feet NGVD in the early1950s.

Substrate type at the planting zones is of primary importance to planting success (Odum and others, 1982; Cintron, 1990; Lewis, 1990a). Mangroves grow on a variety of substrate, however, muds and fine grained sands are optimal soil types (Odum and others, 1982). Planting in dense lime-rock fill is not recommended because it will result in either poor plant establishment or a complete planting failure. Desirable calcareous soils, which were originally found at the historic wetland elevations prior to restoration, may have been compacted by the placement of fill. The compaction is directly proportional to the type and amount of fill. The restoration plan should thoroughly evaluate substrate alternatives relative to success criteria and construction costs. Two techniques of soil modification have been used locally when undesirable substrate conditions exist for the wetlands elevations. First, when desirable soils are within four feet of the wetland elevations, the desirable soils are mixed with the upper layer dense limerock fill using a track backhoe. Field testing has demonstrated that a 50% mixing of limerock fill and buried organic soil results in a cost-effective ($8,000/acre), desirable wetlands substrate. 2) Soil amendments, consisting of an equal mixture of topsoil and sand, are utilized by over-excavating the site by at least one foot and backfilling, to proper wetland elevation with the mixture. The latter technique is generally more expensive, with the added material costs ranging from $20,000 - $30,000 per acre. This technique was used at Site 3, Site 10, and a portion of Site 6 to modify on-site soil conditions (See Appendix).

Topographic survey – A topographic survey is obtained by a certified land surveyor by transferring elevation information from fixed benchmarks to a network of on-site stations, or by aerial photogrammetric mapping. A photogrammetric survey consist of topographically mapping an area, by viewing overlapping aerial photographs through stereoscope viewing equipment and digitizing contours over the resulting three dimensional image. This method is cost effective at large project sites (>10 acres), that are clear of vegetation. This method was successfully utilized at Site 2 and 5 (see Appendix) because of the significant cost savings (approximately 50%) realized versus traditional land survey transect methodologies.

Exotic tree removal is conducted, when feasible, prior to the topographic survey to obtain a more precise fill-quantity estimate for design and construction calculations. Additionally, cost savings are achieved by coordinating heavy-equipment available to assist surveyors in clearing exotic vegetation along survey corridors at heavily vegetated sites.

Establishing proper wetlands planting elevations is a critical factor determining the success of failure of restoration efforts (Crewz and Lewis, 1991; Markley and others, 1992). Therefore, post-construction as-built topographic surveys are required prior to final planting, approval, and payment.

Archaeological evaluations – Sites, which potentially contain historical archaeological cultural artifacts, are inspected by an archaeological specialist prior to clearing activities. A two-phase archaeological monitoring work plan is typically developed. Phase I includes excavating a series of trenches throughout areas determined as significant. This phase identifies areas which will require a more detailed evaluation, and assists in the scheduling and phasing of the actual restoration work. Phase 2 consists of an archaeologist observing the actual excavation work during the restoration. Archaeological evaluations at Site 2 (see Appendix) revealed a 1,000-

year-old (B.P.) human jawbone, along with an assortment of primitive conch shell tools. This is the oldest evidence of human habitation in this area (Zaminillo, 1997).

Environmental permits – Federal, state, and local permits are required for all restoration work. If possible, an on-site pre-application meeting is recommended, with all regulatory agencies participating to discuss project objectives, goals and proposed methodologies. Environmental permit applications include an application form, a project description, a description of construction methods, an environmental impact assessment, a description of turbidity controls, a monitoring plan, a property-ownership deed, an engineer's restoration sketches (signed and sealed) showing plan and cross sectional views of all proposed activities and aerial photographs illustrating the project area, a biological assessment of the restoration area and a permit fee. The permit process typically requires four to six months, depending on the size of and complexity of the restoration.

Project costs and funding – Final design components are given as line item unit costs, as shown in Table 1.

**Table 1**

| Line item | Unit cost |
|---|---|
| Mobilization | 10% of total construction cost |
| Selective clearing, grubbing and Removal of waste | \$4,600 - \$5,200 per acre |
| Floating silt barrier, including maintenance and removal | \$2,000 - \$4,000 lump sum |
| Excavation including final dressing | \$1.50 - \$4.00 per cubic yard |
| Disposal of excavated materials | \$1.55 - \$4.00 per cubic yard (varies by distance to disposal site) |
| Wetland vegetation | |
| Mangroves (1 year old) | \$0.90-\$1.75 |
| Other species (liners) | \$0.50-\$1.30 |
| Other species (one gallon) | \$3.00-\$8.00 |

In general, excavation and disposal unit costs depend on site accessibility and disposal strategies. For example, excavation and disposal at Site 2 were one-half the costs at Site 1 because of the availability of designated disposal sites to recycle beach-quality sand and stockpile non-beach quality sand in close proximity to the excavation site. Vegetation costs are directly related to nursery availability of desired species. Unavailable plant species are occasionally contracted for growing through the construction contract or made available through separate growing contracts. The permitted restoration plans, with associated costs, are then used to 1) develop funding acquisition requests through federal, state and local grant programs, (requires a minimum of six months); 2) develop opportunities for wetland mitigation credits, and 3) achieve restoration with available materials (e.g., desired elevations {+1.2' NGVD) at Site 7 are being achieved with available materials at no cost).

As detailed in the project description (See Appendix), wetlands restoration is primarily funded through local, state, and federal agencies. In addition, large tracts of altered wetlands are being acquired throughout the County with funds from Dade County's Endangered Lands Program, Biscayne Bay Environmental Enhancement Trust Fund, and various state (e.g., Preservation 2000) and federal funds.

## III Restoration

The implementation of restoration plans is achieved through two mechanisms: 1) using open contracts for materials and heavy equipment, with work supervised by DERM staff, and 2) selecting outside contractors through a bidding process that awards the contract to the lowest bidder, qualified to perform the work. For the latter, technical specifications are prepared detailing the following aspects of the project.

- Location of work
- Scope of work
- Summary of quantities
- Detailed restoration drawings
- Permits and licenses
- Limitation of operation
- Procedures and methods
- Site investigation
- Surveys
- As built survey requirements
- Work site and staging site maintenance conditions
- Award of contract
- Time for completion
- On-site field office
- Pre-work conference
- Selective clearing of exotic vegetation

- Site preparation
- Floating silt barrier
- Excavation (including grading and final dressing)
- Trucking of excess material
- Rip-rap
- Culverts
- Planting
- Maintenance performance and payment bond
- Manatee provisions
- Archaeological monitoring

Restoration cost savings is realized in the contractor selection process by detailing cost-effective methodologies and detailing all project components and maximizing construction contract alternatives (e.g., contractor ownership of excavated material, phasing).

The contractor selection process requires from four to six months to complete, and is initiated upon securing dedicated funding. The environmental permitting and funding acquisition processes usually require twelve months to complete. Restoration and enhancement grant funds range from one to two years in duration, with contract time extensions of one year. Restoration projects are scheduled around the natural seeding cycles and optimum site conditions found during the seasonal hydro-periods. Despite administrative delays, large-scale volunteer planting efforts (e.g., Site 2, 150,000 mangroves) have resulted in the successful planting of mangroves throughout all four seasons. This can be attributed to the favorable subtropical climate of south Florida.

The restoration contract specifications are utilized to evaluate design compliance. In addition, restoration monies are also saved through “trouble-shooting” during the construction period. Restoration contract adjustments to enhance the “quality” of the wetlands, can be made by executing contract “change orders”. Archaeological discoveries during the construction phase may also require revisions to the construction schedule.

Prior to planting, all vegetation is inspected by the project manager. Minimally, areas that are vulnerable to erosion are planted immediately, such as edges of flushing canals, and areas adjacent to open water. Other areas can be planted as plants and installers (volunteers) become available.

A performance and payment bond in the amount of twenty percent of the contract amount is required for all contracts. The terms of the maintenance period being on the date of final acceptance of the work and continue for a minimum of one year. Vegetative monitoring is conducted at pre-established photo stations and by aerial qualitative assessments on a quarterly basis. Contracts typically specify that there be 100% survival of plant material after one year. Should the quarterly monitoring by DERM reveal that less than 80% of the planting material is surviving, the contractor is notified immediately and has fourteen calendar days to replant with sufficient material to provide 100% survival.

Success criteria of the projects are based on ongoing planting survivability and information regarding habitat use by fauna. Faunal assessments at restored sites are conducted by volunteer wildlife experts, and school groups within the community. Planting survivability is determined qualitatively using photo-stations and quantitatively using the fixed-quadrat method and line intercept method within restored wetlands. All planting sites are considered highly successful if they have an overall 80% planting survival rate. To date, 52 species of birds have been recorded using the newly restored wetlands, including 18 species of shorebird, 7 species of wading birds and 4 species of tern. In addition, two saltwater crocodiles and four West Indian manatees have been observed within the newly created wetlands at Site 2. Discussions are underway with Florida Department of Environmental Protection (FDEP) to develop marine fisheries larvae and juvenile fish habitat criteria for plan development and follow up fisheries monitoring at project sites.

In the first decade of implementation of the Biscayne Bay Wetlands Restoration program, Miami-Dade Department of Environmental Resources Management has restored and enhanced approximately 300 acres (121.5 ha) of coastal wetlands. Four wetland communities have been successfully established utilizing cost-effective techniques at 10 coastal sites in Miami-Dade County at a total cost of 6.7 million dollars. Sites are summarized in the Appendix.

Public acceptance of this Biscayne Bay restoration work is extremely favorable. Partnerships with various governmental and community environmental groups were developed. The most significant result is the heightened public awareness of Florida's fragile coastal ecosystems. The importance of restoration of these vital communities, not only in Florida but, throughout the world, is essential.

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## APPENDIX - PROJECT DESCRIPTIONS

Site1 **BEAR CUT PRESERVE WETLANDS RESTORATION**

**Size**: 21.5 acres **Completion Date**: 11/96

**Location**: North end of Key Biscayne, FL
25° 44' N, 80° 10' W

**Scope of Restoration:**

- Clearing and removing exotic vegetation, predominantly *Casuarina equisetifolia*.
- Selective clearing of 4 acres.
- Excavating 41,600 cubic yards of dredge spoil material.
- Planting 10 acres of mangroves.
- " 6.2 acres of high salt marsh.
- " 2.8 acre tidally flushed pond.
- Installing 0.5 acre fresh/brackish water pond.
- " a network of inter-tidal flushing creeks.

**Species Planted:**

| | |
|---|---|
| *Acrostichum aureum* | *Juncus roemerianus* |
| *Annona glabra* | *Laguncularia racemosa* |
| *Avicennia germinans* | *Rhizophora mangle* |
| *Batis maritima* | *Scirpus validus* |
| *Borrichia fructescens* | *Sesuvium portulacastrum* |
| *Cladium jamaicensis* | *Spartina bakeri* |
| *Conocarpus erectus* | *Spartina spartinae* |
| *Distichilis spicata* | *Sporobolus virginicus* |
| *Eleocharis cellulosa* | *Suriana maritima* |

**Funding** (% matching): Miami-Dade Water & Sewer (WASA) (95%), Biscayne Bay Environmental Enhancement Trust Fund (BBEETF) (5%)

Total **Cost**: $800,000

Site 2 **BILL BAGGS CAPE FLORIDA STATE PARK WETLANDS RESTORATION**

**Size:** 85 acres **Completion Date**: 85 acres 4/99,

**Location**: South end of Key Biscayne, FL
25° 40’ 47” N, 80° 10’ 10” W

**Scope of Restoration**:

- Clearing exotic vegetation.
- Removing 30,000 cubic yards of solid waste.
- Removing 600,000 cubic yards of dredge spoil material.
- Creating 75 acre of tidally connected mangrove wetlands.
- Installing 3 major flushing connections and culvert connection.
- Installing a network of inter-tidal flushing creeks.
- Creating 10 acres of freshwater isolated wetlands.

**Species Planted:**

*Acrostichum danaefolium*
*Baccharis sp.* *Eleocharis cellulosa*
*Borrichia fructescens* *Rhizophora mangle*
*Cladium jamaicensis* *Spartina bakeri*

**Funding** (% matching): BBEETF (37%), Florida Inland Navigation District (FIND) (12%), South Florida Water Management District (SFWMD) (11%), WASA (10%), US Dept. of Agriculture Forest Service (34%), Village of Key Biscayne (3%).

**Total Cost**: $2.8 million

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Site 3 **FLORIDA INTERNATIONAL UNIVERSITY BAY VISTA CAMPUS WETLANDS RESTORATION**

**Size**: 2 acres **Completion Date**: 12/95
**Location**: North Miami, Florida
25° 54’ 20” N, 80° 8’ 24” W

**Scope of Restoration**:

- Selective clearing and removing exotic vegetation, predominantly *Casuarina equisetifolia*.
- Transplanting 65 desirable native trees.
- Excavating and removing 10,000 cubic yards of dredge spoil.
- Installing 4 inter-tidal flushing channels.
- Planting 2 acres of *Rhizophora mangle* on 3 feet centers.

**Funding**: Dade County Public Works Dept. **Total Cost**: $140,000

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Site 4 **VIRGINIA KEY DUNE/WETLANDS RESTORATION**

**Size**: 5 acres **Completion Date**: 12/99

**Location**: North Miami, Florida
25° 45' 30" N, 80° 08' 21" W

**Scope of Restoration**:

- Clearing exotic vegetation.
- Excavating and removing 13,000 cubic yards of fill material.
- Planting 2 acres of dune community.
- Planting 4 acres of *Rhizophora mangle/Spartina spartina*e wetlands.
- Installing 1 major flushing channel, culvert and a connecting inter-tidal creek.

**Species Planted**:

| | |
|---|---|
| *Avicennia germinans* | *Scaevola plumieri* |
| *Borrichia fructescens* | *Spartina spartinae* |
| *Coccoloba uvifera* | *Suriana maritima* |
| *Hymenocallis latifolia* | *Uniola paniculata* |
| *Rhizophora mangle* | |

**Funding**: (% matching): City of Miami (33%), BBEETF (33%), Florida Dept. of Environmental Protection (FDEP) (33%).

**Total Cost**: $180,000

Site 5 **NATIONAL BULK CARRIER SITE PHASE 1 ENHANCEMENT**

**Size**: 140 acres **Completion Date**: 6/94

**Location**: Bordered on the east by L-31E canal, on the west by SW 107 Avenue and bisected by Military Canal in south Miami-Dade County, Florida.
25° 28’ 57” N, 80° 20’ 53” W

**Scope of Restoration**:

- Making detailed topographic survey.
- Mapping and existing plant communities and soils.
- Removing exotic vegetation, predominantly *Casuarina equisetifolia* and *Schinus terebinthifolius.*

**Funding**: (% matching): SFWMD (50%), BBEETF (50%)

**Total Cost**: $300,000

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Site 6 **OLETA RIVER STATE PARK WETLANDS RESTORATION PHASE I**

**Size**: 13 acres **Completion Date**: 10/90

**Location**: Miami, Florida
25° 55’ 30” N, 80° 07’ 51” W

**Scope of Restoration**:

- Clearing and mulching of exotic vegetation, predominantly *Casuarina Equisetifolia.*
- Excavating 55,000 cubic yards of Intra-coastal Waterway dredge spoil material.
- Planting 13 acres of *Rhizophora mangle* on 3 feet centers.
- Installing a network of inter-tidal creeks.

**Species Planted**:
*Rhizophora mangle*

**Funding**: Dade County Seaport Dept.
**Total Cost**: $300,000

Site 7 **OLETA RIVER STATE PARK WETLANDS RESTORATION PHASE II**

**Size**: 45 acres **Completion Date**: Ongoing

**Location**: North side of the Oleta River, North Miami Beach, Florida
25° 55’ 24” N, 80° 08’ 22” W

**Scope of Restoration**:

- Clearing and removal of exotic vegetation, predominantly *Casuarina equisetifolia*, on the existing 23.5 acres of upland.
- Removing all on-site solid waste (e.g. seawall, concrete pads, mooring piles) remaining from remnant marina.
- Excavating of 58,000 cubic yards of dredge-fill material.
- Filling a 1750 ft. long, 150 ft. wide and 7 to 33 ft. deep L-shaped canal with 167,000 cubic yards of clean fill.
- Installing a network of inter-tidal creeks.
- Planting 28.5 acres of tidally connected *Rhizophora mangle* forest.

**Species Planted**:
*Rhizophora mangle*

**Funding**: TBA **Approximate Cost**: $1.5 million

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Site 8 **OLETA RIVER STATE PARK MANGROVE ENHANCEMENT**

**Size**: 1900 L.F. **Completion Date**: 6/90

**Location**: Immediately south of the Oleta River, west side of Intra-coastal Waterway, North Miami, Florida

**Scope of Restoration**:

- Stabilizing 1,900 linear feet of eroding mature *Rhizophora mangle* forest with natural lime-rock boulders, and filter fabric.
- Installing a network of inter-tidal creeks

**Funding**: SFWMD **Total Cost**: $430,000

Site 9 **HIGHLAND OAKS WETLANDS RESTORATION**

**Size**: 13 acres **Completion Date**: Ongoing
**Location**: Highland Oaks Park
20300 NE 24 Avenue
Miami-Dade County, Florida
25° 57’ 30” N, 80° 10’ W

**Scope of Restoration**:

- Selective removing 8.2 acres of exotic vegetation, predominantly *Schinus terebinthifolius* and *Casuarina equisetifolia.*
- Planting 3 acres of littoral shelf native vegetation.
- Planting 3.0 acres of forested fresh water wetland.
- Planting 8.2 acre river bank and hammock vegetation.
- Re-establishing 250 feet of historical riverbed of the Oleta River.

**Species Planted**:

*Acer rubrum*
*Acrostichum danaeifolium*
*Annona glabra*
*Bacopa spp.*
*Bursera simaruba*
*Canna flaccida*
*Cephalanthus occidentalis*
*Chrysobalanus icaco*
*Cladium jamaicensis*
*Conocarpus erectus*
*Crinum americanum*
*Cyperus odoratus*
*Eleocharis cellulosa*
*Eriocaulon decangulare*
*Ficus citrifolia*
*Hymenocallis latifolia*
*Ilex cassine*
*Juncus effusus*
*Juncus polycephalus*
*Ludwigia repens*
*Magnolia virginiana*
*Myrica cerifera*
*Myrsine floridana*
*Nymphaea odorata*
*Nymphoides aquatica*
*Panicum hemitomon*
*Pontederia cordata*
*Psychotria spp.*
*Quercus laurifolia*
*Roystonea elata*
*Sabal palmetto*
*Salix caroliniana*
*Sagittaria lancifolia*
*Sagittaria latifolia*
*Saururus ceranus*
*Scirpus validus*
*Spartina bakeri*
*Taxodium distichum*
*Tripsacum dactyloides*

**Funding**: BBEETF **Cost Estimate**: $260,000

Site 10 **CHICKEN KEY BIRD ROOKERY RESTORATION (CK)**

**Size**: 7 acres **Completion Date**: 3/97

**Location**: Chicken Key, located in the Biscayne Bay Aquatic Preserve, south Biscayne Bay
Miami-Dade, Florida
26° 37' 12" N, 80° 17' 15" W

**Scope of Restoration**:

- Clearing and removing 4 acres of exotic vegetation, including *Casuarina equisetifolia, Neyraudia reynaudiana, Schinus terebinthifolius, Scaevola taccada, Thespesia populnea, Hibiscus tiliaceus and Acacia auriculiformis*.
- Selective clearing 3 acres of exotic vegetation.
- Excavating 33,000 cubic yards of dredge spoil from the north and central portions of the Key (Spoil sold by contractor reducing restoration cost).
- Restoring 1,200 LF of dunes.
- Planting 150 LF of experimental mangrove in pvc encased tubes.
- Planting 3.7 acres of red mangroves (*Rhizophora mangle*) on 3 foot centers.
- Installing 3 flushing channels (8'-15' wide).
- Installing a network of tidal creeks (900 LF).

**Species Planted:**

*Avicennia germinans*
*Batis maritima*
*Borrichia frutescens*
*Coccoloba uvifera*
*Conocarpus erectus*
*Distichlis spicata*
*Helianthus debilis*
*Iva imbricata*
*Jacquemontia reclinata*
*Mallotonia gnaphaloides*
*Rhizophora mangle*
*Scaevola plumieria*
*Sesuvium portulacastrum*
*Spartina patens*
*Spartina spartinae*
*Sporobolus virginicus*
*Uniola paniculata*

**Funding**: (% of total) Florida Dept. of Environmental Protection (FDEP) (34%), South Florida Water Management District (SFWMD) (24%), Biscayne Bay Environmental Enhancement Trust Fund (BBEETF) (42%)

**Total Cost**: $600,000